A detailed "how-to" handbook to guide the Technology PM and SDD PM Team would go a long way to facilitating these goals. However, *A Manager's Guide to Technology Transition In an Evolutionary Acquisition Environment: A Contact Sport* (August 2002) is an excellent interim publication that can be used now.

The FCS S&T IPT took a detailed look at the state of technology available to realize the Army's desired future combat capabilities and recorded the CTs required and their maturity levels in the TMA. Bottom line: the necessary technology for Increment I exists and will transition, but not without risk. Transitioning that technology from the technology base into development will be a complicated but achievable task that will help transform our Army for the future. A key lesson learned by the FCS S&T IPT is that the S&T community needs to begin to pay as much attention to *transitioning* their technology as they are in making the technology work. To this end, coordination and cooperation between the Technology PM and future project/product managers, users and contractors is crucial to prepare programs for success. Excellent assessment tools are available to provide managers the metrics they need to plan and execute programs. In short, what gets measured gets done.

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RAVEN — New Gun Shakes up FCS

Dr. Eric Kathe, Henry Nagamatsu and Joseph Flaherty

FUTURE COMBAT SYSTEMS
One Team-The Army/Defense/Industry

Packing lots of punch in small packages is a succinct description of the armament requirements for Future Combat Systems. During the past 3 years, a new gun propulsion method has been discovered, analyzed, patented and fired that may usher in a new era of lightweight weaponry. Termed RAVEN for RArefaction waVE guN, it achieves this by decimating the core engineering challenges to lightweight gun integration — recoil and thermal management.

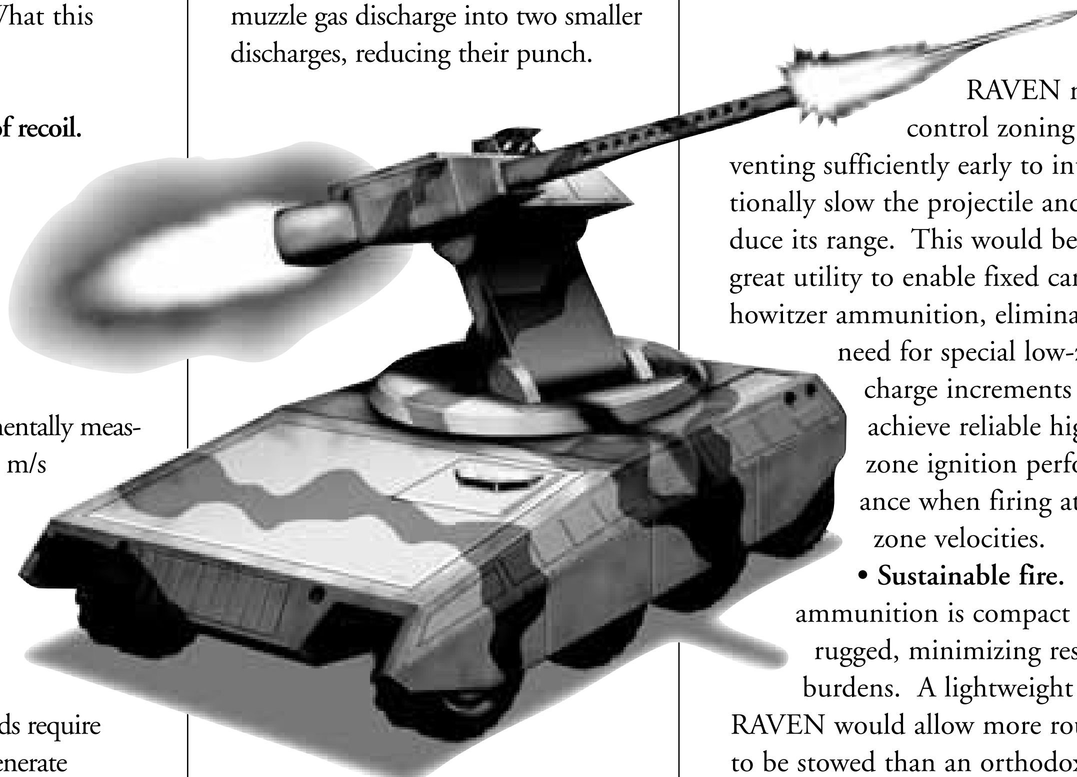
The RAVEN Principle

If the breech of a gun's chamber is suddenly opened while the bullet is being propelled through the bore, a delay time will occur before the pressure loss in the chamber can be communicated forward to the bullet's base. Thus, it is possible to trick the bullet into thinking it is being fired from a closed breech gun when it is not.

How RAVEN Works

When the breech is vented, the pressure in the chamber plummets. This pressure loss propagates through the bore at the same speed that a sound wave would. This phenomenon is termed a rarefaction wave or "thinning of gases" as pressure is lost. If the venting is timed so that the bullet exits the muzzle before the bullet can "hear" the venting, no loss in muzzle velocity will occur. The gases vented from a RAVEN's breech are driven through an expansion nozzle. This nozzle cools and depressurizes the gases as they are accelerated to high rearward velocities generating thrust. This thrust dramatically reduces the recoil energy imparted to the cannon. What this achieves follows:

- **Reduction/elimination of recoil.** RAVEN firing of a tank round such as the 1,650 meters per second (m/s) M829A2 is anticipated to eliminate 95 percent of the recoil energy. More than 80 percent has been experimentally measured when firing a 1,150 m/s NATO standard 35mm Oerlikon round from a RAVEN, while 75-percent reductions are anticipated for a high-zone 686 m/s howitzer. Theoretically, faster rounds require more propellant gas to generate more thrust.
- **Double the firing rate.** Hot propellant gases heat up guns during firing. Removing these gases from the bore before the bullet exits the gun dramatically reduces barrel heating. With reduced heating, greater burst fire may be achieved and a higher firing rate sustained without overheating the barrel. RAVEN also reduces blow-down duration and recoil cycle time. Further, RAVEN has demonstrated that it can be engineered to pneumatically blow out the cartridge case, eliminating the extraction sequence for cased munitions.
- **Reduced blast.** When guns fire bullets, only about 30 percent of the energy released is imparted to the bullet. Most of the remaining energy is manifest as muzzle blast. RAVEN favorably alters this balance between bullet energy and blast energy by leveraging a large portion of the remaining energy to drive a recoil compensating jet. This reduces the energy available to generate blast and signature. Further, cooling and depressurizing the gas reduces the propensity for secondary flash. RAVEN then splits orthodox muzzle gas discharge into two smaller discharges, reducing their punch.



- **Enables lightweight cannons.** Guns remain heavy, despite advances in material technology, for two principal reasons: their thermal mass is required to manage the heat generated during burst-fire; and their inertia aids in recoil management. Lighter guns "kick" harder during firing than heavier guns. Exploratory development and firing of a 350-pound 5-inch gun for the Navy (program Fire-Box) has proven successful at a 10-fold reduction in barrel weight, but system integration is impractical. Reduction of recoil and barrel heating are the keys to enabling lightweight guns.
- **Infinite zoning.** Although RAVEN's focus has been applied to venting sufficiently late so that the bullet velocity is unaffected, advantages may be realized by venting earlier. Further reductions in recoil and barrel heating may be realized, although with some loss in muzzle velocity. Taken to a logical extreme, control of the muzzle velocity may be achieved.

  RAVEN may control zoning by venting sufficiently early to intentionally slow the projectile and reduce its range. This would be of great utility to enable fixed cartridge howitzer ammunition, eliminate the need for special low-zone charge increments and achieve reliable high-zone ignition performance when firing at low-zone velocities.
- **Sustainable fire.** Gun ammunition is compact and rugged, minimizing resupply burdens. A lightweight RAVEN would allow more rounds to be stowed than an orthodox gun increasing the combat system's staying power.
- **Clean chamber.** The advantages of caseless ammunition have been appreciated for decades. The disadvantages include the tradeoff between a rugged and combustible case construction and beach closure methods that are fast and those that tolerate residue. RAVEN achieves a rearward supersonic blow-down within the chamber, entraining and flushing burning embers, firing residue and any debris present in the gun.

Implementation Challenges

Integration of RAVEN technology requires two challenges to be met — vent mechanics and gun system integration that accommodates back-blast. Many methods may be conceived to vent the chamber of a gun during the interior ballistic cycle. The most reliable approach engineered thus far has been a blow-back, bolt-operated RAVEN, inspired by guns such as the M3A1 0.45 caliber "grease gun." In this system, the breechblock is free to recoil rearward within an extended chamber. By altering the breechblock's weight and the distance required to uncork the back of the gun, vent timing may be engineered to occur when required.

Experimental testing of a 35mm RAVEN demonstrated complete vent reliability with a standard deviation in vent timing of less than 1 percent. Since the venting mechanism is directly driven by the same propellant gases that are concurrently driving the bullet down the bore, this approach is robust.

Alternative approaches include directly coupling the recoil of a light gun barrel within a mount to open the vent, balanced chamber valves and active burst disks. Nonrecoil-based approaches may be anticipated to "misfire" on rare occasion, perhaps one in 10,000 shots. For RAVENs with less than 100-percent vent reliability, the gun barrel must be free to recoil rearward within the mount. Technologies analogous to the engineering of "crumple zones" in automobiles may be applied to ameliorate these rare failures without catastrophic consequences.

More development is essential in this area to mature RAVEN into a formidable weapons platform. Analysis and experimental findings to date have not surfaced any insurmountable barriers to achieving a reliable and useful weapon system.

Virtually all armament technologies generate blast. Orthodox guns generate formidable muzzle blast. The incorporation of muzzle brakes to manage recoil redirects the muzzle "blast back" at the vehicle, generally making "hatches-open" operation impossible without violating the requirements of Military Standard 1474D, *Noise Limits for Army Materiel*. Nevertheless, orthodox gun blast always emanates from the muzzle. This is a most familiar and comfortable configuration because it allows the gun's breech to recoil within the turret. However, this comes at the price of consuming precious under armor swept volume.

External guns such as the 105mm Stryker mobile gun system and 175mm M107 gun allow for convenient and direct integration of a RAVEN. Oscillating turrets, such as the French 75mm AMX-13, also provide for convenient nozzle integration. External guns are amenable to RAVEN because they enable longer recoil strokes without costly under armor volume consumption.

Precedents for back blast abound. Firing missiles or rockets generally results in a large back-blast zone, exceeding that of prior-art recoilless rifles. Such systems have been combined with infantry since the days of the 106mm M50 Marine Ontos and continue to this day with the M3A3 Bradley Tube-launched Optically tracked Wire-guided missile and Multiple Launch Rocket System. Although it can be said RAVEN has less energy to drive blast, our understanding of this blast and means to mitigate the consequences is immature. Focus thus far has been placed on understanding and validating RAVEN's interior ballistic performance. With validation complete, focus may now be applied to design challenges.

Meeting the Objective Force's combined lethality, deployability and sustainability requirements entails revolutionary armament technology. Combined with advances in composite material technology, RAVEN promises to reduce gun system weights by factors of two or more. It will virtually eliminate recoil kick to stop shaking up our combat systems.

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